Fact Sheet #1: Functions of Riparian Areas for Flood Control

HOW DO RIPARIAN AREAS PROVIDE FLOOD CONTROL?

Naturally vegetated riparian areas (uplands as well as floodplains) serve a number of beneficial functions for flood control. An undeveloped, vegetated floodplain reduces the force, height and volume of floodwaters by allowing them to spread out horizontally and relatively harmlessly across the floodplain. Water that floods into vegetated floodplains reenters the main channel slowly, enabling it to be soaked up by the "sponge" of floodplain wetland soils and streamside forest leaf litter. Living, decaying and dead vegetation on riparian lands that falls or extends into the water provides numerous barriers against moving water, which slows it down so water is not delivered downstream as quickly. Such vegetation also intercepts and detains runoff from adjacent upland areas that would otherwise flow directly into rivers and exacerbate flooding conditions downstream. The root systems of streamside forest and emergent aquatic vegetation keep pores of the soil open so that two to three times more water can infiltrate the soil compared to lands used for cultivation or grazing.

In addition, trees, shrubs and herbaceous plants in riparian areas use large amounts of water in transpiration, which in effect, transfers floodwaters to the atmosphere. Several thousand gallons per acre of water are used by plants each day, thereby drying the soil and making more room in the "soil sponge" for floodwater. The combined effect of all of these functions is a significant reduction in peak flows and flooding downstream. Naturally vegetated riparian forests thus help prevent thousands of dollars in property damage and obviate the need for human-made flood control measures and structures.

What alterations to riparian areas impair their ability to provide flood control?

Removing streamside forests from riparian areas impairs their ability to provide flood control in several ways. Floodwater detention is substantially reduced by removing the natural barriers of live, decaying and dead vegetation from the forest floor. Removing streamside forests will also result in an increase in soil compaction and reduction in soil porosity. All of these impacts combine to cause a significant decrease in infiltration and a subsequent increase in the speed and amount of flood runoff. Furthermore, floodwater reduction through transpiration is likely to be reduced, as grass transpires much less water than forest vegetation. Last but not least, excessive sedimentation resulting from the removal of vegetative cover from riparian areas reduces flood storage, as eroded sediments settle out of the current and fill channels and deeper spots on the river so they can no longer convey or hold as much water. This reduction of storage capacity increases peak discharges and the likelihood of flood damage.

Placing impervious surfaces such as roofs and parking lots within riparian areas impairs their capacity to detain and absorb flood waters and runoff from adjacent uplands, and increases the volume and speed of runoff from the riparian area into adjacent streams, resulting in increased flooding and storm damage downstream and the subsequent risk of serious damage to lives and property. Increased watershed imperviousness typically amplifies normal streamflow patterns. Not only does it result in "higher highs" as stormwater, with little or no opportunity to infiltrate the soil, is directly discharged into rivers and streams, exacerbating downstream flooding, impervious surfaces result in "lower lows" when, during periods of low precipitation, the lack of previous infiltration into groundwater reduces baseflow and causes many urbanized streams to stagnate, putrefy and even dry up completely. Stormwater management systems for impervious surfaces typically only mitigate (lessen the severity of) but do not eliminate this problem.

The placement of buildings or other structures within the floodplain or floodway portion of the riparian area is likely to reduce floodwater storage and conveyance, thereby increasing the risk of flood damage to that or other preexisting buildings or structures. Even if the proposed alteration is on a portion of the riparian area that lies uphill from the 100-year floodplain, any alteration that decreases the riparian area's ability to absorb precipitation through gradual infiltration into the ground, such as the removal of forest cover or an increase in impervious surfaces, will contribute to an increase in the frequency, duration and severity of flooding events downstream.

Structural attempts at flood control, such as confining watercourses into narrowly corseted channels and levees, have the effect of raising both the velocity and the height of any subsequent flood flow and make it all the more frightening and destructive when a river breaks through defenses, as has repeatedly happened in the Midwest. [The effect can be like that of a bursting dam.] Channelization of meandering streams cuts the water storage capacity of those streams and causes water to flow more rapidly downstream, exacerbating flooding and storm damage downstream. An increase in water velocity also increases a river's erosive power, placing bridge supports, embankments and other vulnerable areas at greater risk of being undermined. Even if channelized river segments and, on a smaller scale, drainage pipes for a low-lying development, have the effect of conveying flood flows quickly away from that particular location, they will nevertheless increase peak flows downstream. In other words, the cumulative impact of altering riparian areas for the purpose of accelerating the rate at which floodwaters move downstream will exacerbate the severity, duration and frequency of flooding events downstream: the flooding problem is not controlled; it is merely relocated from one spot to another.

Why are vegetated riparian areas along smaller streams as significant for flood control as along the larger rivers?

A large proportion of the water in a river is contributed by the smaller tributaries. If riparian areas along these brooks and streams are altered in a manner that impairs their flood control function, the cumulative impact of streams discharging flood flows into rivers at a greater volume and velocity will result in worsening flooding in mainstem river communities, even if mainstem floodplains are safeguarded against further development. Furthermore, the same development is likely to have a relatively greater negative impact on flooding conditions in an adjacent small stream than the same project would have along a larger river (e.g., the runoff from one large parking lot can itself be enough to overwhelm a small stream channel).

What are some best managment practices for riparian areas to maintain and enhance their flood control function?

Alterations of riparian areas (through structural attempts at flood control or otherwise) can throw a river's delicate equilibrium with its floodplain out of balance in often unpredictable ways, sometimes resulting in much unforeseen damage. The most effective means to avoid such damage and to protect the flood control functions of riparian areas is to preserve and/or restore them to a naturally vegetated condition, letting the rivers flow and flood where they may, and to avoid and minimize the removal of streamside forests and the placement of buildings and other impervious surfaces within riparian areas. Particular attention should be made to maximizing forest cover on riverine uplands, which, due to their steeper slopes, have the greatest potential for exacerbating flooding conditions when detention and infiltration capacities are reduced due to forest removal. Quoting a U.S. Army Corps of Engineer report made in 1972: "Nature has already provided the least-cost solution to future flooding in the form of extensive [riverine] wetlands which moderate extreme highs and lows in streamflow. Rather than attempt to improve on this natural protection mechanism, it is both prudent and economical to leave the hydrologic regime established over millennia undisturbed. In the opinion of the [Army Corps] study team, construction can add nothing." It is interesting to note that among the 17 natural valley storage areas that the Corps found critical to flood control, several lie some distance from the Charles mainstem and are connected to it by streams or brooks. This is an important point to remember: areas critical to flood control in a watershed are often distant from the mainstem.

What are some additional benefits of keeping floodplains naturally vegetated?

Maintaining or reestablishing vegetation in riparian areas increases the water-holding capacity of soil, which helps to recharge groundwater supplies. The slowing and dispersal of runoff and floodwater by floodplain vegetation allows additional time for this water to infiltrate and recharge groundwater aquifers. Floodplain soils and vegetation can also help to purify the water as it filters down to the aquifer. Once there, the groundwater can reemerge and seep back into surface water during the drier months and help reduce the frequency and duration of low streamflows and the higher temperatures, higher pollutant concentrations and other adverse conditions to riverine ecosystems brought on by periods of low streamflow. Last but not least, naturally vegetated floodplains function as important fisheries and wildlife habitat (see respective fact sheets for details).

Fact Sheet #2: Functions of Riparian Areas for Storm Damage Prevention

HOW DO RIPARIAN AREAS PREVENT STORM DAMAGE?

Rivers and streams, serving as conduits of gravitationally-induced energy in the form of streamflow, are constantly in a state of flux. Storm events typically cause rivers to swell in size and velocity, frequently spreading out over adjacent lands and even changing direction and cutting new channels within the floodplain. The volume and erosive force of stormflows can cause substantial damage to homes, businesses, cropland and roads and other infrastructure. This damage is not restricted to the floodplain, as surging, swollen rivers can dig into and undermine steep streambanks, causing slope subsidence and subsequent damage to homes and other property at a considerable height above the water.

Retaining a floodplain in an undeveloped, vegetated condition reduces the force, height and volume of stormwaters by providing ample opportunity for them to spread out horizontally and relatively harmlessly across the floodplain. Vegetation on and above the streambank provides friction against moving water, which slows it down so water is not delivered downstream as quickly. Riparian vegetation also intercepts and detains runoff from adjacent upland areas that would otherwise flow directly into rivers and exacerbate storm damage downstream. In addition, vegetated streamside buffers help block storm debris (e.g., flotsam and jetsam) carried along by stormwater from entering cropland, pastures and other riparian areas, thereby minimizing the need for post-storm cleanup.

Keeping riparian areas naturally vegetated allows the vegetation itself to absorb much of the storm's fury. Vegetated areas dissipate the energy of storm-generated waves and provide considerable resistance to streambank erosion. Plants are endowed by nature with considerable capacity to withstand storm-driven winds, waters and ice. Leaves, branches, even whole trees uprooted in storms maintain their usefulness as they become food and shelter for aquatic organisms and the many forms of terrestrial wildlife inhabiting riparian areas. In the meantime, the streamside forest heals itself through the regrowth of vegetation in storm-damaged areas. Furthermore, the natural sinuosity and complexity of river and stream channels helps to dissipate the rampaging energy of stormwater.

What alterations to riparian areas impair their ability to prevent storm damage?

The two major types of alterations to riparian areas that impair their ability to prevent storm damage are: (1) the placement of buildings and other damageable property within floodplains, steep slopes or other locations that are susceptible to storm damage, and (2) the clearing of vegetation, particularly if it is replaced with impervious surfaces such as roofs and parking lots. The placement of buildings or other structures within the floodplain or floodway portion of the riparian area is likely to reduce floodwater storage and conveyance, thereby increasing the risk of storm damage to that or other preexisting buildings or structures.

Removing vegetation from riparian areas and replacing it with impervious surfaces eliminates the benefits vegetated areas provide in moderating the severity of storm events. While storm runoff from vegetated areas tends to be attenuated both in speed and volume, runoff from impervious surfaces occurs much more quickly, with negligible reductions in volume. The result is that runoff from paved areas tends to be much "flashier" than vegetated areas, leading to a "spikier" discharge curve. In other words, impervious surfaces can actually amplify the effect of storms and the subsequent risk of serious damage to lives and property. Even if the proposed alteration is on a portion of the riparian area that lies uphill from the 100-year floodplain, any alteration that decreases the riparian area's ability to absorb precipitation through gradual infiltration into the ground, such as the removal of forest cover or an increase in impervious surfaces, will contribute to an increased likelihood of storm damage downstream.

Levees, retaining walls and other man-made devices intended to prevent storm-related damage to riverside development are often ineffective, as the immense property damage caused by the 1993 floods along the Mississippi River and the recent costly floods in the Pacific Northwest will attest. Attempts to constrict the water into a channel have the effect of constricting this excessive energy into an increasingly powerful current. When the river breaks its restraints its capacity for destructive action has been magnified. Channelization of meandering streams cuts the water storage capacity of those streams and causes water to flow more rapidly downstream, exacerbating flooding and storm damage problems downstream. An increase in water velocity also increases a river's erosive power, placing bridge supports, embankments and other vulnerable areas at greater risk of being undermined.

Even if channelized river segments or storm sewer collection systems have the effect of conveying storm flows quickly away from that particular location, they will nevertheless likely result in increasing peak flows downstream. In other words, alteration to riparian areas for the purpose of accelerating the rate at which storm waters move downstream is likely to exacerbate the severity, duration and frequency of storm-related damage downstream.

Last but not least, the increased speed and volume of storm water discharge running off pavement and other unvegetated surfaces is likely to result in a serious degradation in downstream water quality. This is due not only to the washing off of accumulated oil, gasoline and other pollutants from parking lots, but also due to an increase in the frequency and severity of combined sewer overflows ("CSOs"). The more impervious surfaces, the more stormwater; the more stormwater, the greater risk that stormwater will get into and overwhelm sewer pipes and treatment plants, increasing the likelihood that raw or partially treated sewage will be discharged into rivers and coastal embayments.

Why are vegetated riparian areas along smaller brooks and streams as significant for preventing storm damage as along the larger rivers?

A large proportion of the water in the state's rivers is contributed by the smaller tributaries. If riparian areas along these brooks and streams are altered in a manner that impairs their ability to absorb and detain stormwater, the cumulative impact of streams discharging storm runoff into rivers at a greater volume and velocity will result in worsening stormwater-related damage to vulnerable structures and river communities downstream. In addition, the fragility of riparian areas is often accentuated in small headwater stream reaches. These small streams are the most vulnerable to human disturbance because they respond dramatically and rapidly to alterations on adjacent lands and are the most sensitive to changes in riparian vegetation in the surrounding watershed. Furthermore, many of the smallest headwater tributaries tend to be located on some of the steepest-sloping and erosion-prone lands within the watershed.

What are some best management practices (BMPs) for riparian areas to maintain and enhance their storm damage prevention function?

Riparian areas prevent storm damage most effectively when they are retained in a naturally vegetated state and kept relatively free of buildings, roadways and other man-made structures and activities vulnerable to storm-related damage. Rivers need room to swell in size and change shape and location within the floodplain in response to storm events. Vegetated areas along rivers help to absorb the force as well as volume of stormwaters, thereby lessening the severity of impacts downstream. Locating structures or other vulnerable land uses within the riparian area simply places them in harm's way and increases the likelihood that they'll suffer storm-related damage. The best way to prevent such damage is to avoid it in the first place by keeping activities vulnerable to storm damage as far away from rivers and streams as possible.

Where alteration in riparian areas is unavoidable, projects should maximize the amount of land retained in and/or restored to a naturally vegetated condition, to minimize the volume and speed of storm-related runoff. BMPs intended to address stormwater management issues may, unless carefully designed, implemented and maintained, nevertheless fail to serve other recognized functions of riparian areas, such as fisheries and wildlife habitat protection, pollution prevention and groundwater aquifer recharge.

Fact Sheet #3: Functions of Riparian Areas for Wildlife Habitat

WHAT IS THE SIGNIFICANCE OF RIPARIAN AREAS FOR WILDLIFE HABITAT?

Riparian corridors (i.e., rivers, streams and adjacent lands) are particularly valuable habitats for wildlife. This includes many of what are ordinarily thought of as "upland" species as well as wetland species. For example, many upland animals need access to rivers and streams for hunting and drinking, particularly in the winter when other water sources may be frozen over. The junction between rivers, streams and adjacent riparian land is especially high in ecological diversity and biological productivity because gravity is constantly moving energy and matter along with the current and because so many animals spend their lives both in water and on land. The high value of riparian areas as wildlife habitat is also due to the abundance of water combined with the convergence of many species along the edges and ecological transition zones between aquatic/wetland, aquatic/upland, wetland/upland and river channel/backwaters habitats.

Interaction between rivers and riparian lands helps create and maintain a high level of habitat diversity.

Rivers play a major role in shaping the landscape and creating habitat for flora and fauna. The habitat along rivers and streams is as diverse as the watercourses themselves, ranging from cobble-strewn brooks to tidal creeks and wide floodplain rivers. Natural vegetation along higher gradient rivers and streams provides large woody debris to the channel that helps form "pool-riffle" habitat critical to many aquatic species and the terrestrial species dependent upon them. Many low-gradient rivers and streams are sinuous by nature; that is, they tend to move about naturally, creating new channels and abandoning old ones. Natural features such as sandbars, undercut banks, oxbows and floodplain pools resulting from a stream or river's interaction with adjacent lands are created, undergo change through time, and eventually disappear, while the overall pattern (e.g., meandering, braiding) remains constant, at least on some larger spacial scale and longer time scale. This form of dynamic equilibrium is a singular property of rivers and accounts for much of the high biological diversity and productivity of riverine systems.

The dynamic equilibrium between the waterways and the land creates a corresponding dynamic equilibrium of life within a river system. For example, successive plant and animal communities occupy a meander loop as it is transformed from an active channel to an isolated oxbow intermittently connected to the main flow during floods, and finally to a wet depression on the floodplain. As long as the river is allowed to freely interact with adjacent vegetated riparian areas, a diversity of habitats in various stages of ecological succession will be maintained. If, on the other hand, the channel is stabilized and isolated from the adjacent riparian area by retaining walls, levees and the like, the many organisms that depend on sandbars, undercut banks, oxbows, floodplain forests and other river-created habitats will begin to disappear.

Importance of riparian vegetation for wildlife

Vegetation (whether living, decaying or dead, standing or fallen) plays a key role in the function of riparian areas as suitable wildlife habitat. Streamside vegetation provides food and shelter for many species. Wildlife foods (seeds, buds, fruits, berries and nuts) are found in abundance within naturally vegetated riparian areas. The shade, detritus and coarse woody debris provided by streamside forests are very important for healthy fisheries, which are in turn a key food for many wildlife species. Leaves, branches, even whole trees uprooted by the river or other natural forces become food and shelter for aquatic organisms and the many forms of terrestrial wildlife inhabiting riparian areas. Logs falling into streams often divert stream flow into new pathways, increasing the complexity of the channel, which helps to maintain a diversity of habitat niches for riverine plants and animals. Last but not least, some wildlife inhabiting riparian areas, through their actions, create habitat for other wildlife species (beavers are the best known example of this locally).

Riparian areas serve as critical corridors for wildlife movement

Another characteristic of naturally vegetated riparian areas of particular value to wildlife is their connectivity function. River and stream systems are key elements of our state's ecological infrastructure. Besides serving as important dwelling habitat per se, undeveloped lands along river and stream corridors provide vital connective lifelines that enable wildlife movement necessary to maintain healthy wildlife populations. Loss of these connective corridors results in habitat fragmentation, a major cause of wildlife decline and even extinction. For example, many species of reptiles, amphibians and mammals need the ability to disperse to new habitat to set up new territory for successful feeding and breeding. This allows for the continuous exchange of genetic material between species populations, a critical factor in maintaining species' resilience to disease and other adverse impacts. It is key, therefore, to maintain undeveloped and naturally vegetated corridors between habitats of a sufficient width to enable animals to travel safely by land from one habitat to another. Allowing habitats to become isolated "islands" surrounded by development will cause them to lose much of their ecological value even though the habitat itself is not directly impacted.

Connections to uplands within and beyond the riparian area also perform vital ecological functions and need to be preserved as much as possible. Many species of amphibians rely on riverine habitat during the breeding season and then spend most of their lives in upland habitat, often at a considerable distance away. The reverse is true for many reptiles. Protecting riverine wetlands will not in itself safeguard the continued existence of the full habitat these organisms need. Protecting access to undeveloped uplands associated with adjacent rivers, therefore, is key to maintaining a healthy functioning ecosystem.

Riparian areas are important for common as well rare species

Although riparian areas serve as key habitat for a number of state-listed rare species of wildlife, it's important to remember that a naturally vegetated riparian area is considered to be significant for wildlife habitat protection even if no rare species are known to make their homes there. In addition to the fact that a number of migratory species, many of them rare, rely on undeveloped river corridors as migration routes, many of our more common resident species would nevertheless become threatened were they to lose the remaining undisturbed riparian habitat they depend upon. Furthermore, a particular riparian area may be performing an important function for wildlife habitat if it serves as a connection for species to travel between two adjacent areas providing good wildlife habitat, even if relatively few wildlife species are found residing within that particular riparian area itself.

What species of animals are dependent upon riparian areas for all or a portion of their life cycle?

Mammals: Many mammals, birds, reptiles and amphibians are dependent on undeveloped, vegetated riparian areas along rivers and streams. Mammal species dependent upon on the habitats provided by rivers, streams and associated ponds and wetlands include mink, muskrat, otter, water shrew, bog lemming, beaver and moose. Many other species, however, spend much of their lives within the habitats immediately surrounding waterways; they are dependent on mixed upland and lowland habitat. Species in this category include everything from raccoon to deer, which often forage in the water, to our eight species of bats, which often forage on insects above the water. All of these species, as well as many others, occasionally use river corridors as travel routes.

Birds: Some species of birds are especially adapted to river life. The Louisiana and Northern water thrushes, for instance, are usually encountered in river corridors. The spotted sandpiper is frequently visible along river bars and shorelines. Many other shorebird species occur along rivers where appropriate mud bars develop. Belted kingfishers patrol rivers from the headwaters to the sea in search of small fish. Osprey flourish along rivers. Many species of herons and bittern depend to a large extent on riparian corridors for food, roosting and nesting sites. Bald eagles frequent riverine corridors in search of fish and roosting areas. Birds such as cormorants, night herons and gulls follow river systems for many miles inland in search of good feeding areas.

Rivers and their adjacent landscapes are also critical resident waterfowl. Black and mallard ducks and blue-winged and green-winged teal nest and raise their young in riverine marshes and wetlands. Wood ducks and hooded mergansers nest in tree cavities in swampy bottomlands. A less obvious river corridor user is the woodcock, or "timberdoodle", a terrestrial bird which follows and relies on vegetated wetlands within river corridors as its primary feeding and nesting habitat. River corridors are also major migration routes for many species of songbirds such as vireos, flycatchers, thrushes, tanagers and wood warblers.

Amphibians and Reptiles: Amphibians, which by definition require water or at least damp habitats in order to reproduce, frequently utilize riparian areas. At least one species, the mudpuppy salamander, is restricted to specific river drainages. Three semi-aquatic salamanders, the northern two-lined, northern dusky and northern spring salamanders, live in and along streams and small rivers. The preservation of river corridors encompassing considerable upland habitat is required to maintain other species of amphibians, for many spend most or all of their lives away from open water habitats. The wood frog and four species of mole salamanders, for instance, breed only in temporary vernal pools and spend their lives on or beneath the forest floor, but may require vegetated riparian areas to disperse to new territory.

Naturally vegetated riparian areas are just as vital for resident reptile species. Individuals of several species, including the musk turtle, snapping turtle, painted turtle and northern water snake may spend their entire lives in riverine habitats. Other species, such as the Blanding's turtle, spotted turtle, diamondback terrapin and ribbon snake, inhabit wetlands which are often associated with river systems. All turtles lay eggs and, hence, even the most aquatic species require upland habitat for their nesting activities. Corridor protection is especially important for the semi-aquatic wood turtle. The wood turtle spends much of its life in brooks and streams, but it inhabits surrounding upland habitats during the warmer months of the year. The three known bog turtle populations appear to require, alkaline fens containing rivulets.

Reptiles and amphibians (known collectively as "herps") are far less mobile than birds and mammals. While the latter groups can cross developed areas and recolonize lost ground, often in a matter of years, range expansion by herp species is more likely to be measured in decades. Unbroken corridors, especially riparian corridors of natural habitat, are required to ensure the continued health and expansion of our herp species, particularly the amphibians, as well as small mammals such as shrews and moles. These animals may be unable to cross even moderately sized areas of unsuitable habitat (such as parking lots).

Rare and Endangered Species: Rivers provide critical habitat for many rare and endangered species. Rivers provide vital habitat for globally endangered freshwater mussels, many rare dragonflies, endangered tiger beetles, Blanding's turtles, Britton's violet and river bulrush. State-threatened bird species such as the least bittern, king rail, pied-billed grebe and the federally threatened bald eagle also inhabit river corridors in the state. Some types of riverine habitats that rare species depend upon are floodplain forests, river sandbars, claybanks, freshwater tidal marshes and extensive marshes dominated by emergent vegetation.

What alterations to riparian areas may impair their ability to function as wildlife habitat?

Alterations to the riparian area that are likely to cause the most adverse impact from a wildlife perspective are those that degrade or eliminate an area's functionality as habitat (e.g. replacing vegetated areas with pavement) and/or interfere with its connectivity function (e.g., establishing a barrier to wildlife movement to and/or along a stream corridor). Development has encroached on river and stream corridors in many areas, fragmenting wildlife habitat and leading to a serious decline in the quantity and quality of wildlife habitat in these areas. It is crucial that we save the linkages that are still intact, as well as taking advantage of opportunities to restore connectivity through the reestablishment of vegetation along previously devegetated riparian areas wherever possible.

- <u>Lawns and Golf Courses</u>

The replacement of naturally vegetated riparian areas with manicured and/or highly managed landscapes such as lawns and golf courses has at least three adverse impacts on wildlife. First, such manicured areas typically require periodic and substantial application of pesticides, herbicides, fungicides, fertilizers and other chemicals that often cause direct harm to wildlife through ingestion or bioaccumulation through the food chain, or lead to habitat-degrading pollution in adjoining water bodies. Second, the vegetation in manicured landscapes typically contains less species diversity than wild areas, usually reducing the diversity and overall abundance of wildlife using such areas. Third, the instinct to keep such manicured areas "neat and tidy" often results in the removal of dead standing or fallen trees, leaves and brush, all of which provide important food or shelter for a wild variety of riparian wildlife. To the extent that such "tidying up" involves the use mechanized equipment such as power mowers, chain saws, leaf blowers and the like, such devices can further discourage wildlife from using the area.

- <u>Roads and Driveways</u>

The placement of new roads and driveways located within riparian areas can also result in serious fragmentation and degradation of wildlife habitat. Generally speaking, the wider the road, the closer it is located to the river, and the greater the number and speed of vehicles using the road, the greater the adverse impact. The first impact, the removal of trees and other vegetation and subsequent regrading of the road right-of-way, typically destroys whatever habitat existed within that area beforehand. Automobile fluids, deicing chemicals and other toxics washing off roadways can pollute adjacent areas and degrade their value as wildlife habitat. Another serious impact is that roads act as a barrier to many forms of wildlife movement. Even relatively narrow rural roads can be a significant obstacle to the movement of sensitive amphibian species. Stormwater catch basins are insidious amphibian traps. Granite curbs along roadways can be enough of a barrier to effectively prevent amphibians and some turtles from safely crossing a road. Fatal collisions of wildlife attempting to cross roadways with motorized vehicles (i.e., roadkill) is a significant cause of death for many of the state's wildlife species, large and small. Such an "impact" may extend beyond the death of the animal struck and affect mates and offspring.

- <u>New Homes, Yards and Pets</u>

The placement of new homes within the riparian area can pose an additional set of problems for wildlife. In addition to the impacts associated with roads, driveways and manicured landscapes discussed above, homes with pets and/or other domesticated animals can lead to further degradation or loss of wildlife habitat and even death of wild animals. The clearing of forest or other natural vegetation within the riparian area to establish paddocks for horses, sheep and other grazing animals degrades the utility of that area for native species. Other adverse impacts of pets may extend beyond the houselot to affect riparian areas at a considerable distance. Dogs allowed to roam frequently cannot resist the temptation to chase after deer and other animals. The resulting increased stress on these wild animals can significantly impair their ability to care for themselves and their families. Wildlife will often simply avoid areas with high dog activity, thereby losing what might be otherwise suitable habitat. Last but not least, house cats are known to be exceptionally destructive to wildlife, especially nestling birds and wild small mammals.

- Flood Control Structures

Other alterations that have the potential to cause an adverse impact on wildlife habitat within the riparian area include structural flood controls such as retaining walls, levees and the like, which can isolate a river from its floodplain and serve as a barrier to the very floodwaters that create and maintain floodplain wildlife habitat, considered by many wildlife biologists to be of especially high ecological value.

Why are vegetated riparian areas along smaller streams as significant for wildlife habitat as along the larger rivers?

Wildlife use of riparian areas along smaller brooks and streams, although somewhat different in character from the major rivers, is still quite extensive. Many species utilize vegetated riparian areas during all or part of their life cycle regardless of the size of the adjacent watercourse. In fact, several sensitive species (e.g., the spring salamander) thrive only in cold, unpolluted springs and small streams. Last but not least, as many river corridors have already been extensively developed, the areas which remain in a relatively pristine condition (and as such are likely to have the best quality wildlife habitat) tend to be located on the smaller tributaries.

What are some best management practices for riparian areas to maintain and enhance their function as wildlife habitat?

The best way to protect wildlife habitat functions within the riparian area is to maintain and/or restore as much of it as possible in an undisturbed, naturally vegetated state. Many studies have shown the superiority of natural vegetation over cropland and other heavily managed landscapes for wildlife diversity and productivity. These studies have also found that, in general, much larger streamside forest buffer widths are needed for wildlife habitat purposes than for water quality purposes. In fact, 300 feet is the generally accepted minimum width needed to provide adequate habitat and movement corridors for most wildlife species. For example, surveys of songbird use of riparian areas recommend that riparian forests be at least 100 meters (330 feet) wide to provide some nesting habitat for neotropical migrants.

Where some alteration within a riparian area is unavoidable, it should be designed and implemented in a manner that minimizes any loss of connectivity with adjacent vegetated lands as well as any loss of function within the site itself. In general, the further away the proposed work is from the river, the smaller the adverse impact on wildlife habitat and movement. In addition, natural features within a riparian area that may be of particular value to wildlife should be identified and safeguarded from disturbance if at all possible. Such natural features include: large dead standing trees (used by hawks and eagles for nesting and roosting); large trees with cavities (used by nesting owls, wood ducks, hooded mergansers and other animals); large dying trees (bats roost under the loose bark); stone walls and rock piles (used by snakes and small mammals); floodplain and other seasonal pools and water-holding depressions (used by amphibians for breeding), as well as adjacent uplands; understory tangles (used as cover by many wildlife species); large woody debris in streams (provides basking areas for turtles and snakes); streambank burrows (where the homes of weasels, otters and muskrats are typically located); sandy soils with good sun exposure (used by turtles as nesting areas); large trees overhanging the river (flycatchers, kingfishers, osprey, and other birds use them for feeding perches); large stands of conifer trees (often used by deer as wintering areas); hollow trees and logs (suitable as dens for some mammal species) and fallen shaded logs (preferred by some salamanders for habitat). If stream crossings are unavoidable, road widths should be kept to the minimum possible. In addition, bridges are generally preferred over culverts for stream crossings, as they present less of a potential barrier to fish and wildlife.

Last but not least, previously disturbed riparian areas that continue to remain in a degraded condition may present opportunities for restoring wildlife habitat functions. For example, any work that removes pavement or lawn at the water's edge and replaces them with a vegetated buffer of native trees and shrubs is likely to benefit wildlife as well as fisheries and the other functions of riparian areas. Local conservation commissions, foresters, the state Divisions of Fisheries and Wildlife and/or Forestry, watershed associations and land trusts have some expertise in this area and may provide some guidance on designing effective riparian wildlife habitat restoration measures.

Fact Sheet #4: Functions of Riparian Areas for Fisheries Protection

WHAT IS THE SIGNIFICANCE OF RIPARIAN AREAS FOR FISHERIES PROTECTION?

Naturally vegetated riparian areas perform many beneficial functions for fisheries. These functions may be grouped into the broad categories of habitat creation, water quality, water quantity, and food supply. An example of a water quality function is the shade provided by a streamside forest tree canopy that helps to moderate water temperatures (which is necessary to maintain the relatively high levels of dissolved oxygen needed by trout and other aquatic organisms). An example of a food supply function is the detritus (decomposed vegetative matter) from decaying leaves, twigs, etc. which fall into the stream and provide a key energy source fueling the base of the aquatic food chain. Insects that fall from overhanging trees and shrubs are a particularly important food source for fish in small forested streams.

Habitat creation and food supply: On low-gradient rivers and streams, large woody debris (tree trunks, roots, etc.) falling and/or extending out into the water add structure to the stream, providing needed cover for fish to hide from predators and prey. On smaller and/or higher-gradient rivers and streams, large woody debris helps to create the "pool-riffle" habitat that is essential for many fish species and many aquatic insects they depend upon for food. A pool is an area of deep, slow water; a riffle is an area of shallow, swift water. Pools provide cover, shelter and resting areas for sportfish. Riffles reaerate the water, produce most of the fishes' food, and are used as spawning and feeding areas. Fish expend considerable energy maintaining their positions when feeding in riffles. Nearby pools serve as resting and hiding areas as well as important refuges during low-flow periods. Nearly all streamfish require clean gravel to spawn and larger cobbles or boulders for resting and cover. The smaller fine bottom materials (silt and clay) generally are unsuitable for spawning sites since they smother eggs and young fish.

Water Quantity: Riparian forests can minimize disruption of aquatic communities by maintaining streamflow during droughts and reducing streambank erosion and other adverse impacts of flood events. Fish can actually get evicted from their in-stream habitats by floods that can literally wash them out as well as alter the pools, riffles, etc. that they call home. Streamside forests reduce the quantity and velocity of flood flows both by storing and absorbing flood waters in the floodplain and by contributing debris to the stream that absorbs the force of flood flows and gives fish a place of shelter to resist being swept downstream. Streamside forests help maintain streamflow in summer so that fish don't lose their habitat by having it dry up on them.

Water Quality: Last but not least, streamside forest areas serve as living biological buffers to absorb excessive levels of sediment, nutrients and other pollutants generated by adjacent development as well as from the stream itself. This function is key to maintaining the high water quality needed by a host of riverine organisms. For example, many benthic macroinvertebrates such as caddis flies and mayflies, both favorite foods for trout, are very sensitive to pollution. Furthermore, streamside forests keep levels of erosion and/or sedimentation below that which would smother the streambottom gravels necessary for successful fish spawning.

What alterations to riparian areas impair their ability to protect fisheries?

Activities within riparian areas that: a) reduce its natural vegetative cover, especially any reduction in streamside forest cover; b) contribute to an excessive level of nutrients or sediments getting into adjacent watercourses; c) involve the use and/or release of heavy metals, pesticides, herbicides and other toxics; or d) increase its imperviousness are likely to result in a degradation of a riparian area's fisheries protection function.

Excess nutrients: Phosphates and nitrates leaching from septic systems or running off fertilized cropland, pastureland, lawns, golf courses and the like, contribute to excessive levels of nutrients in streams, triggering a chain reaction of adverse impacts. Excessive nutrients promote excessive algae and aquatic nuisance weed growth which, in addition to inhibiting the growth of other aquatic vegetation of greater value to aquatic organisms, reduces the level of dissolved oxygen in the water. The resulting hypoxic (low oxygen) or anoxic (zero oxygen) state can cause fish kills and decreases in aquatic insect populations, as well as disruptions in the normal food web and water chemistry balance.

Excessive aquatic weed growth triggered by excess nutrients also has an adverse impact on the quality of the fishing experience. Not only do anglers have to put up with the constant nuisance of weed-choked fishing tackle, canoe paddles and boat propellers, the reduced dissolved oxygen caused by excessive plant growth creates adverse conditions for trout and other highly desirable game fish (which depend on high dissolved oxygen levels) and will eventually result in a shift in species composition toward carp, suckers and other "coarse" fish more highly tolerant of low dissolved oxygen levels. (It should be noted that chemical or mechanical removal of aquatic vegetation from waterways has its own share of adverse impacts and is not a long-term solution nor an effective substitute for reducing excessive nutrient inputs.)

Excessive sedimentation: Sediments carried into streams from sources such as sand washing off from wintertime road sanding operations and silt from tilled cropland and other exposed soils harm fisheries in a number of ways. Excessive sediments increases the water's turbidity (cloudiness) which decreases the transmission of light, which in turn affects plant production. Plant roots anchor the bottom against wave action and disturbance by bottom-feeding fish such as carp. The stems and leaves of floating and emergent plants help to absorb wave energy. When aquatic plant beds are eliminated through excessive sedimentation, turbidity problems may further worsen. Loss of plants also means loss of important fish food like snails and aquatic insects that feed on aquatic plants.

Trout and other fish can tolerate short episodes of high levels of suspended sediment, because they exude a protective mucus on their skin and gills that traps and continually flushes particles away. However, this protective mechanism requires metabolic energy and constitutes a stress on the fish at the same time as its ability to find food is reduced (because of the increasing cloudiness of the water the sediment has caused). Trout and other gamefish rely on relatively clear water to see their prey (and fishermens' lures). In addition to sight feeding, many species of game fish exhibit complex reproductive and social behaviors that depend on visual cues. A reduction in visibility interferes with these visual cues and thereby reduces reproduction success.

Furthermore, excessive sediment fills in the spaces between and beneath pebbles and cobbles on the stream bottom where it can cover up streamside gravel spawning areas and prevent the emergence of recently hatched fish fry. Sediment covering stream gravels also degrades benthic macroinvertebrate habitat. Excessive levels of suspended sediment harms filter-feeding invertebrates who are forced to take in less food (organic particles) and more soil particles. As with excessive nutrients, the long-term effect of excessive sediment and turbidity in rivers is to wipe out suitable habitat for sensitive game species such as trout and replace them with species such as carp and catfish that are tolerant of high turbidity levels and other degraded habitat conditions.

Elevated stream temperatures: One of the most direct adverse impacts of the removal of streamside forests is the resulting increase in stream temperature due to loss of shading. As water temperature increases, its capacity to hold oxygen decreases. Since oxygen is used in the decomposition process, elevated water temperatures reduce a stream's ability to absorb organic matter and assimilate excess nutrients and other pollutants without causing oxygen depletion. Lowered oxygen levels can cause fish mortality and a shift in aquatic community populations. The more desirable "cold-water" species such as trout will be replaced by less desirable "warm-water" fish that can tolerate elevated water temperatures and lowered oxygen levels.

Fish are cold-blooded animals whose body temperatures correlate closely to water temperatures. At warmer temperatures, the fish's metabolic rate speeds up and requires more oxygen at the very time that dissolved oxygen levels in the water are dropping due to the higher temperatures. Removing streamside forests may also alter thermal regimes in a manner that interferes with the thermal cues necessary for successful metamorphosis of aquatic insect species, leaving few larvae or insects for the fish to eat.

The majority of potentially harmful nutrients that enter watercourses are attached to sediment particles. At lower temperatures, the nutrients from excess fertilization of cropland, golf courses, etc. are insoluble and remain attached to these particles. Slight increases in temperature will produce substantial increases in the quantity of elements released into the water, significantly reducing water quality of the stream. In the meantime, these same sediments are themselves likely to increase stream temperature even further (turbid water tends to be warmer than clear water due to increased heat absorption), resulting in additional degradation of habitat for "cold-water" species).

Impervious surfaces: Pavement, roofs and other impervious surfaces are particularly harmful to fisheries. The increasing "flashiness" of runoff from impervious surfaces triggers a cycle of streambank erosion and habitat degradation. A major expression of channel instability is the loss of instream habitat structures, such as the loss of pool and riffle sequences and overhead cover and reduction in the wetted perimeter of the stream, all of which cause a loss in the quality and quantity of suitable habitat conditions for fisheries. Impervious surfaces also collect pollutants deposited from the atmosphere, leaked from vehicles or derived from other sources. During storms, accumulated pollutants are quickly washed off and rapidly delivered to aquatic systems.

Stream temperatures throughout the summer are higher in urban watersheds, and the degree of warming appears to be directly related to the imperviousness of the surrounding watershed. Many studies consistently show that the diversity of benthic macroinvertebrates (a key fish food and an overall indicator of a stream's ecological health) is poor when watershed imperviousness exceeds 10-15%. It is worth noting that these same studies determined that streams flowing through urbanized areas with intact streamside forests had higher benthic macroinvertebrate diversity than those that did not, given the same level of urbanization.

Other pollutants: Heavy metals, a common constituent in runoff from roads, parking lots, roofs and industrial areas bioaccumulates in fish tissues, threatening their health as well as the health of any other animals (including humans) that consume them (thereby dampening the enthusiasm of many recreational anglers). Heavy metals can also affect the reproductive rate and life span of aquatic organisms and hinder photosynthesis in aquatic plants fish rely upon.

Pesticides and herbicides typically get into rivers via runoff or leachate from adjacent farms, yards, golf courses, right-of-way spraying and other highly managed and/or manicured landscapes. These poisons in sufficient toxicity and/or concentration can cause the death of fish and other aquatic and terrestrial organisms. Even at sublethal concentrations, these chemicals can bioaccumulate in fish tissues. As with heavy metals, pesticide residues in fish threatens their health and the health of any other animals and people that consume them. Pesticides also harm other aquatic organisms and aquatic plants fish rely upon.

Last but not least, pathogens (bacteria and viruses) getting into rivers and streams via urban runoff, malfunctioning sewers and septic systems located within riparian areas degrades fisheries by introducing disease-bearing organisms to fish and other aquatic life. The activity of pathogenic organisms also increases with stream temperature, creating a synergistic adverse impact when streamside forests are cleared for development.

Why are vegetated riparian areas along smaller brooks and streams as significant for protecting fisheries as along the larger rivers?

It is especially important from a fisheries protection perspective to preserve corridors of natural vegetation along the smaller brooks and streams. Most of the annual flow in the smaller headwater streams is provided by groundwater (natural spring seeps) that, in turn, is replenished by rainwater falling onto and infiltrating the soil under vegetated areas. Since water seeps slowly through the soil, the surface water flowing in streams can represent rainwater that fell days, weeks or even months ago. This regular, continuous seepage of groundwater that keeps streams flowing is called "baseflow".

Baseflow is critical to stream life and water quality. Low flow periods are typically the most stressful periods for aquatic organisms, resulting in crowding due to less available habitat, elevated water temperatures in the summer and greater freezing in the winter. Sportfish, fish food animals, and water plants require a stable, continuous flow of water, particularly during dry periods. Groundwater discharge is a major source of streamflow for smaller streams, especially during hot and dry summers, where the discharge both augments the streamflow and mitigates harmful temperature increases. This groundwater discharge is key to maintaining adequate water levels and temperatures in streams to support aquatic life.

The failure to maintain vegetative cover on or keep impervious surfaces out of riparian areas adjacent to smaller brooks and streams is likely to result in a significant loss of groundwater recharge and increase the frequency, duration and severity of low flow conditions. In the smaller streams, where flows are already modest in size to begin with, a reduction in baseflow would be especially harmful. Small streams deprived of groundwater flow may even dry up completely, a condition that is obviously extremely stressful if not fatal to fish and other aquatic organisms.

Due to their modest size, small streams and brooks are especially vulnerable to excessive sediment, nutrients and other pollutants, simply because there is a smaller volume of water available to flush out and/or and assimilate these pollutants. All other things being equal, the same development is likely to have a relatively greater negative impact on a small stream's fishery than the same project would along a larger river (the lower water volume in the smaller watercourse will result in higher nonpoint source pollution concentrations). Maintaining a living filter of natural vegetation along smaller brooks and streams both intercepts pollutants before they reach and degrade the sensitive smaller streams as well as enables groundwater recharge and low flow augmentation to help dilute pollutant concentrations.

Because of their small ratio of stream bottom width to shoreline, small headwater streams are especially vulnerable to harmful increases in temperature due to removal of shading from streamside forests. Removal of shading also increases evaporation rates, thereby increasing the duration and frequency of periods where such streams will be too shallow for fish to navigate or even run dry completely, a condition which is obviously harmful if not lethal to fish and other aquatic organisms living there.

Optimum spawning sites for important game fish frequently exist in headwater streams, even though these same fish may spend their remaining time in larger rivers. An increase in water temperature in headwater streams may result in a decrease in fish reproduction. Fortunately, the effectiveness of streamside forest buffers at controlling water temperature increases as stream size decreases. And if water temperatures are kept cool by streamside forests in the upper portion of the watershed, the tributaries will provide a significant beneficial cooling effect on the main watercourses during the summer, when flows are lowest and temperatures are highest.

Studies have shown that streambank forests insulate streams from excessive freezing as well as heating. Excessive freezing can reduce or eliminate the water necessary for fish to survive. The lower streamflow levels combined with ice obstructions creates adverse conditions for fish navigation and other life processes. (Note that water withdrawals from streams during the winter (for snowmaking, e.g.) can have this same effect, as the less water left in the stream, the more vulnerable it is to freezing.) Maintaining deep pools of water as a feature of instream habitat is very important for fish to survive winter conditions, as deeper pools are much more resistant to freezing than are shallower waters.

Even where inaccessible to fish, the small headwater brooks and streams and adjacent riparian areas remaining in a relatively pristine condition provide high levels of water quality and quantity, sediment control, nutrients and woody debris for downstream reaches of the watershed. Thus, especially in the highly degraded systems, headwater streams serve as critical ecological anchors for riverine systems and important refuges for biodiversity. As many of the fisheries in mainstem rivers have already suffered serious degradation, it is the smaller tributary streams, especially the "coldwater" streams capable of supporting naturally reproducing wild trout, where preventing further encroachments into riparian areas is arguably of greatest value from a fisheries perspective.

What are some best management practices (BMPs) for riparian areas to maintain and enhance their fisheries protection function?

The best way to maximize a riparian area's fisheries protection function is to maintain and/or restore as much of it as possible in an undisturbed, vegetated (preferably forested) state, most importantly at the water's edge. Although a streamside forest at least 80 feet wide on each side of a river or stream is adequate to ensure maximum stream shading, as much of the remainder of the riparian area as possible should be kept in or restored to a naturally vegetated state in order to effectively filter out excess sediments, nutrients and other pollutants before they reach the water, as well as maintain adequate groundwater recharge.

Retaining canopy shade along streams where most of the forest cover has been removed for other land uses is still important. Riparian trees, even in isolated blocks, may still be valuable because stream temperature drops rapidly once a stream reenters a forested riparian area. Studies have shown stream temperatures dropping from 80 to 68 degrees after the stream had flowed through 400 feet of shaded channel.

Logs, stumps and other large woody debris in and/or overhanging the water (even where undercut by the current) should be left undisturbed as much as possible to maximize its value as a food source and instream habitat for fish and other aquatic organisms as well as helping to keep harmful sediment movements under control. Connections between rivers and adjacent floodplains should also be maintained, as floodplains are valuable foraging, spawning and nursery habitat for some fish species. This was dramatically demonstrated during the Great Midwest Flood of 1993 when the Mississippi River reclaimed much of its floodplain. The flood reconnected the river to traditional spawning areas, resulting in a significant increase in fish populations.

Fact Sheet #5: Functions of Riparian Areas for Protecting Public & Private Water Supplies

WHY IS IT IMPORTANT FOR PUBLIC & PRIVATE WATER SUPPLY PURPOSES TO MAINTAIN AND/OR RESTORE HIGH WATER QUALITY IN OUR STREAMS?

What if our town, home, etc., is wholly supplied by well water?

Many public and a number of private wells are potentially threatened with contamination from pollutants getting into adjacent rivers, streams and other surface waters. Why is this the case? Contrary to popular belief, water withdrawn from many wells does not exclusively originate from groundwater aquifers. Groundwater and surface water are, for the most part, interconnected. For example, many if not most high-yield aquifers are located in areas with extensive stratified drift deposits, often found directly underneath rivers and adjacent floodplains and uplands. Surface water can flow into the ground or vice versa in these areas, depending upon precipitation, streamflow and other factors. Many public water supply wells and a number of private wells are deliberately located in close proximity to rivers in order to tap into these stratified drift aquifers that are hydrologically connected to adjacent rivers, thereby maximizing yields (i.e., the volume of water available to be withdrawn by a well at that location).

As a result, water withdrawn from these streamside wells may include a significant proportion that is "pulled" (through a process called induced infiltration) out of adjacent rivers and streams and into the well. Another way of explaining this is that wells typically have a "zone of contribution", the area of land and subsurface from which water in a well originates. If a river or stream passes through this zone, then there is a significant possibility that some of this stream water will be induced to flow into an adjoining well. Hydrologists have determined that wells may induce infiltration from rivers and streams up to 1000 feet away, especially in periods of below-average precipitation. What this means is that in order to protect such wells from contamination, it is necessary to protect the adjacent rivers and streams as well as the aquifer from contamination. In other words, as pollution-generating activities on riparian lands may contribute to a degradation of downstream water quality, it is important to minimize or eliminate these degrading activities on lands upstream of streamside wells as well as surface water withdrawal points.

Why should we be concerned about pollutants in rivers and streams contributing water to public water supplies if our community treats our source water before we use it?

Even if your water is treated before drinking, there are several reasons why it is still important to keep pollutants out of the source water as much as possible. First is the issue of cost. The more polluted the source water going into the treatment plant, the more communities will need to spend on disinfection (e.g. chlorination) and other treatment and the greater likelihood that their water treatment plant facility will have to be upgraded to handle the additional pollutants. On the other hand, the cleaner the source water, the less money has to be spent on chlorine and other water treatment chemicals, with additional savings resulting from the reduced energy and manpower needed to operate treatment equipment. Protecting current sources from pollution is also easier and cheaper than losing them to contamination and then having to pay for developing a new water supply (if indeed there are any uncontaminated sources left in town) or having to purchase water elsewhere.

Second, and arguably more important, better source water quality has a public health benefit to water consumers. There are several types of pollutants - nitrates for example - that are particularly difficult and/or expensive to remove from drinking water. Studies have shown that Giardia, an intestinal parasite that is difficult to remove from source water (the Russian city of St. Petersburg's water system may be permanently contaminated with it) is ten times more common in water receiving urban pollution than water from protected forested watersheds.

Third, fish and other aquatic animals as well as humans may suffer from the consequences of having to add chemicals to source water in order to help render it safe for drinking. Degraded source waters may need to have disinfectants and algicides such as chlorine and copper sulfate added during the treatment process. These chemicals may pose no danger to humans but are themselves (or via by-products) harmful to aquatic organisms once the water is discharged back into rivers and streams. Chlorine has another major problem: it combines with organic matter to produce chemicals called disinfectant byproducts. The EPA has already set drinking water standards of 100 parts per billion for one group of byproducts called trihalomethanes because of their potential to cause cancer.

How does the retention and/or establishment of a vegetated riparian area along rivers and streams help to protect public and private water supplies?

Naturally vegetated riparian areas along rivers and streams act as a living filter to intercept and absorb excess nutrients, sediment and other pollutants carried along in runoff from adjacent development as well as by the river itself. Several different and complementary processes within the vegetated riparian area collaborate to accomplish this. First, living, decaying and dead vegetation within the riparian area provides a multitude of barriers that slow down runoff from adjacent lands. Large woody debris (e.g. tree trunks and roots) extending or falling into the water accomplishes the same result for the stream itself. This slowdown enables a number of pollution-attenuating functions to occur. Much if not most of the runoff filters into the soil within the riparian area, where sediments are trapped and where excess nutrients, heavy metals and many other pollutants either adhere to or are taken up and sequestered in living plant tissue or are broken down into less harmful substances by soil bacteria and other microorganisms. A similar phenomenon occurs in the river itself, where sediments are held back by the large woody debris, which also provides ample surface area to support a large population of microbes that consume excess nutrients and other pollutants that have already gotten into the water.

Without the protection afforded by streamside forests, rivers and streams are vulnerable to being degraded by a host of pollutants, many of which pose specific problems relating to public and private water supplies. Excessive sediments carried into rivers by stormwater and other means harm water supplies by damaging water treatment pumps and other equipment, increasing treatment costs to remove the sediment, and reducing reservoir storage capacity. Sediment can also decrease river bottom infiltration, reducing the yield of nearby wells. In addition, chlorine is generally less effective as a water treatment disinfectant if the water has a high level of suspended sediment particles. Excessive nutrients (phosphates and nitrates) coming from fertilized lawns, golf courses and other sources harm water supplies by prompting excessive algae growth which can lead to odor and taste problems in drinking water, thereby increasing treatment costs. A related problem is that removing streamside forests leads to an increase in water temperature and sunlight, both of which can contribute to increased algae growth. Pesticides and herbicides running off and/or leaching into rivers from adjacent farms, yards, golf courses, etc. can be expensive and/or difficult to remove from drinking water, and those that are not effectively removed may pose carcinogenic or other health risks or cause the abandonment of the supply.

Metals coming from urban runoff have several adverse impacts. First, they increase the costs of treatment to remove the metals. Second, they also can form deposits in pipes, reducing their carrying capacity. Third, they can color water, leaving stains on fixtures and clothing. Last but not least, there is a possible human health hazard from toxic metals that may not be removed by prior treatment. Pathogens (viruses and bacteria), a common constituent of urban runoff as well as getting into rivers via malfunctioning sewer or septic systems, increasing public health risks while, once again, increasing treatment costs to render the water safe to drink. Lastly, removal of the shade provided by streamside forests increases stream temperature (and the smaller the stream, the greater the impact on stream temperature, because a smaller volume of water will heat up more easily than a larger one). This can lead to accelerated water supply pump/equipment corrosion while promoting algae growth, producing odors and bad taste, and creating a more favorable environment for pathogens.

In conclusion, nature itself has provided a very efficient, low-cost and low-maintenance water treatment mechanism in the form of naturally vegetated riparian areas. As the state's remaining inventory of relatively pristine waters continues to come under threat of contamination, we must consider all such water sources as potentially necessary for public or private water supply. Even if there are no current public or private surface or groundwater withdrawal points downstream from a particular riparian area proposed for development, such points may be necessary for water supply in the future. In the meantime, keeping these riparian areas naturally vegetated is a far more effective and less expensive way to safeguard safe drinking water over the long term than building elaborate facilities to treat increasingly polluted water.

Fact Sheet #6: Functions of Riparian Areas for Groundwater Protection

HOW DO NATURALLY VEGETATED RIPARIAN AREAS PROTECT GROUNDWATER?

Most groundwater gets there by way of gravity and the infiltration of surface water through exterior layers of soil and rock. The two major pathways for surface water to enter the ground is (1) precipitation falling on land and percolating through the soil and (2) water in rivers, streams and other water bodies seeping through their sides and bottoms into the adjoining ground. Groundwater can also seep back into surface water, playing a vital role for smaller rivers and streams (discussed further below).

Lands adjacent to rivers and streams (also known as riparian areas) maintained in and/or restored to a naturally vegetated condition are especially effective in enabling precipitation and runoff to infiltrate the soil and pass through to the water table (the "surface" of the groundwater). The uncompacted soil beneath streamside forests, for example, is honeycombed with cavities and passageways created by decaying roots, burrowing animals and fungi, making it a highly porous medium that readily absorbs precipitation. In the meantime, ground cover and organic debris accumulated on the forest floor acts as a barrier to help slow down and deter surface water runoff after rainfall or during snowmelt, thus providing additional time for infiltration to take place.

Furthermore, the streamside forest acts as a living filter to help prevent groundwater contamination by intercepting and absorbing excess nutrients, sediment and other pollutants carried along in runoff before it percolates down to the water table. This is accomplished by several biochemical processes, including the uptake of excess nutrients and heavy metals into living plant tissues and the breakdown of these and other pollutants into less harmful substances by soil bacteria.

How can riparian areas affect the quantity and quality of groundwater as a source of public and private water supply?

Many groundwater wells are sited in riparian areas, to take full advantage of the typically higher water yields found in those locations. For example, areas of stratified drift (deposits of water-bearing sand and gravel that serve as major aquifers) are often found directly underneath rivers and adjacent floodplains and uplands. This means that a significant portion of the "zone of contribution" (the area of land and subsurface from which water in a well originates) for such wells is made up of riparian areas.

This is important from both a groundwater quantity and quality standpoint. Keeping riparian areas naturally vegetated will help maintain high infiltration rates, thereby replenishing the groundwater and recharging the aquifer, which is key to the long-term sustainability of groundwater-based public water supplies and private wells. In the meantime, the naturally vegetated area's cleansing action will help ensure the purity of water entering the aquifer. On the other hand, if riparian lands within a well's zone of contribution are used in a fashion that enables pollutants to get into the groundwater, then there is a significant possibility that some of this polluted groundwater will enter and contaminate the adjoining well.

Why is maintaining high groundwater quantity and quality important for rivers as well as people?

As mentioned previously, groundwater can and often does reemerge as surface water, and groundwater discharge into rivers and streams has a beneficial effect on both the quantity and quality of water in the recipient watercourse. This is particularly true for the smaller headwater streams, where most of their annual flow is attributable to groundwater reentering the surface as natural spring seeps that, in turn, are replenished by rainwater falling onto and infiltrating the soil under vegetated areas. Since water seeps slowly through the soil, the surface water flowing in streams can represent rainwater that fell days, weeks or even months ago. This regular, continuous seepage of groundwater that keeps streams flowing is called "baseflow".

Baseflow is critical to stream life and water quality. Low flow periods are typically the most stressful periods for aquatic organisms, resulting in crowding due to less available habitat, excessive water temperatures in the summer and greater freezing in the winter. Sportfish, fish food animals, and water plants require a stable, continuous flow of water, particularly during dry periods. Groundwater discharge is a major source of streamflow for smaller streams, especially during hot and dry summers, where the discharge both augments the streamflow and mitigates harmful temperature increases. This groundwater discharge is key to maintaining adequate water levels and temperatures in streams to support aquatic life.

The failure to maintain vegetative cover on riparian areas adjacent to smaller brooks and streams is likely to result in a significant loss of groundwater recharge and increase the frequency, duration and severity of low flow conditions. In the smaller streams, where flows are already modest in size, a reduction in baseflow is especially harmful. Small streams deprived of groundwater flow may even dry up completely, a condition that is obviously extremely stressful if not fatal to fish and other aquatic organisms.

Furthermore, as the level of pollutants in groundwater is typically lower than in surface waters, groundwater discharge into rivers and streams helps augment streamflows available to dilute and flush out toxic chemicals and other pollutants. As rain falling on a vegetated streamside buffer readily infiltrates into the underlying groundwater, it will further help to dilute concentrations of pollutants originating in adjacent land uses before they reach the river. Although this has the most visible and dramatic impact on smaller streams, larger rivers benefit as well from the cleaner flow of groundwater-augmented tributaries as well as discharges of groundwater directly into mainstem rivers. As it is the larger rivers that are burdened with pollutants coming from industrial and other wastewater treatment discharges, the addition of cleaner, cooler groundwater gives a significant boost to the mainstem rivers' ability to assimilate pollutants, especially during the drier months.

Last but not least, scientists have recently discovered the hyporheic zone, a biologically active subsurface area associated with riparian areas, whose existence is primarily dependent upon groundwater. The hyporheic zone is that area of the land underneath and bordering the river on both sides where there is a constant interchange of water from the ground to the stream and back again. The hyporhiec zone is important to riverine organisms, especially invertebrates, during periods of disturbance to riverine ecosystems (floods, droughts and so forth). The hyporheic zones have also been identified as intimately associated with fish spawning and rearing areas and are an important source of energy and nutrient transport. The zones can extend from a few centimeters on small streams to include large floodplain aquifers in gravel-bed rivers. The importance of the hyporheic zone and its role in providing refugia (i.e., secure places to retreat to when adjacent habitat has been degraded) in streams is just now being recognized.

What alterations to riparian areas impair their ability to protect groundwater quantity and quality?

The biggest impediment to a riparian area's ability to replenish groundwater is the construction of impervious surfaces such as paved driveways and parking lots and the roofs of buildings that prevent precipitation and runoff from infiltrating slowly into the ground. Other uses of riparian land have lesser but nevertheless significant adverse impacts. Streamside forests disturbed by logging, trampling by livestock, and heavy recreational use by people can destroy the forest floor and severely compact forest soils, drastically reducing their porosity and infiltration rate. Streamside forests cleared for cultivation or grazing are likely to experience a 33-67% reduction in water infiltrating the soil and entering the groundwater than if the forests, with their more porous soils, had been left in place and maintained in a relatively undisturbed condition. Replacing streamside forests with lawns will also result in a reduction in groundwater recharge. There is less biological activity in the soil underlying a mowed lawn than there is in forest soil, so the earth is less tunneled and less water percolates down into the groundwater. This is particularly harmful for riparian areas adjacent to small streams, where, as stated previously, groundwater seeping into streams is a critical source of streamflow, especially during the hotter, drier months.

Ditching, tiling, channelization and similar alterations to riparian areas and river and stream channels intended to increase the efficiency with which precipitation and flood water is collected and conveyed downstream is likely to reduce opportunities for the water to infiltrate into the ground and recharge groundwater levels. Removing streamside vegetation and/or the natural sinuosity of river and stream channels will produce a similar result, as channels bordered by vegetation slow the water down and allow for more groundwater replenishment than if the stream is channelized and the water flows away quickly without having a chance to sink into the adjacent groundwater.

As groundwater levels are frequently found at or just below the surface of many riparian lands, providing little or no vertical buffer, groundwater beneath riparian areas is especially vulnerable to degradation from polluting activities. The list of potentially polluting land uses is quite extensive, ranging from cropland and lawns (which are typically treated periodically with pesticides, herbicides and fertilizers) to heavy metals and automobile fluids accumulating and running off of parking lots. Malfunctioning and even fully operational septic systems that have been sited within riparian areas can contribute to excessive levels of nutrients and even pathogens to the adjacent groundwater.

A major adverse impact of such groundwater pollution is the potential contamination and forced treatment or even closure of public and private water supply wells, which as stated previously, are frequently sited in riverfront areas. For example, without the presence of vegetated riverfront areas to filter and absorb the high levels of nitrate ions that are a standard component of septic system leachate, they can seep into the adjoining groundwater aquifer and can move by subsurface flow to water supply withdrawal points as well as streams. High concentrations of dissolved nitrates in well water can necessitate well closure. Excessive sedimentation resulting from alterations to riparian areas, while not harmful to public health per se, may nevertheless decrease river bottom infiltration and reduce the yield of nearby wells. For other types of pollutants (hazardous wastes, for example), cleaning up groundwater supplies once contaminated is a very expensive, often times impossible, undertaking.

What are some best managment practices (BMPs) for riparian areas to maintain and enhance their groundwater prevention function?

Maintaining and/or restoring riparian areas to a naturally vegetated condition is, in general, the best way to ensure maximum infiltration of precipitation, stormwater runoff and flood water into the soil and an influx of uncontaminated water to aquifers and other groundwater resources. The best way to maximize infiltration of runoff discharged into riverfront areas is to site the discharge at the outer edge of the riparian area and disperse it as much as possible through the use of a level lip spreader or other device that converts the runoff into sheet flow. This will maximize the water's beneficial interaction with the streamside forest soil. Keeping riparian lands naturally vegetated will also preclude the vast majority of alterations to riparian areas that could potentially pollute the groundwater.

It should be recognized, however, that naturally vegetated streamside buffers, as effective as they are in filtering out most forms of pollution before they reach the groundwater, may not offer complete protection for some types and/or concentrations of pollutants. For example, untreated runoff from a gas station discharging into a vegetated riparian area may contain pollutants of such a nature and amount that they can not be effectively absorbed by streamside forests alone. Runoff from this and similar activities must undergo pretreatment through a specially designed filtering mechanism before it is allowed to infiltrate into the soil. Many states have a stormwater management policy which prohibits infiltration of stormwater from areas with higher pollutant loads without pretreatment. State and local regulatory authorities should be consulted when there is any doubt as to whether it is appropriate to allow runoff from a potentially polluting activity to infiltrate the ground without pretreatment.

.Fact Sheet #7: Functions of Riparian Areas for Pollution Prevention

WHY ARE THE USE & CONDITION OF RIPARIAN LANDS PARTICULARLY IMPORTANT FROM A POLLUTION PREVENTION PERSPECTIVE?

Water pollution problems persist despite improvements in wastewater treatment. Passage of the state and federal Clean Water Acts 25 years ago have brought about a substantial reduction in water pollution from major point sources such as industrial and municipal wastewater discharges. Periodic sampling of pollutant levels in many rivers and streams indicates that further improvements in water quality have stagnated over the past decade, however, with some watercourses actually deteriorating in quality. Over 60% of the state's rivers and streams routinely sampled for water quality continue to fail state and federally mandated Class B ("fishable and swimmable") standards during all or part of the year.

A major reason for the continuing lack of significant improvements in water quality is the increasingly larger share of pollution attributable to nonpoint sources such as runoff from roadways, parking lots and other development on lands adjacent to rivers and streams (otherwise known as riparian areas). Such development on riparian areas, coupled with the removal of streamside vegetation, has also reduced rivers and streams' natural ability to cleanse themselves. Reducing nonpoint source pollution from riparian lands that are already developed (through, e.g., retrofitting storm drains with pollution-filtering devices) can be cumbersome and expensive. Maintaining riparian areas in and/or restoring them to a naturally vegetated condition will, on the other hand, partially or completely prevent nonpoint source pollution generated by adjacent development from getting into rivers and groundwater, as well as helping to mitigate pollution levels in the river itself regardless of their source.

What are the major types of nonpoint source pollutants and the land uses responsible for them? What adverse impacts can these pollutants cause on other functions and values of rivers and riparian areas?

Nutrients (phosphates and nitrates,e.g.) are needed by all living organisms to carry out basic life processes, but in excess they can throw riverine systems out of balance. Excess nutrients in the form of manure or commercial fertilizer applied to farmland, yards and golf courses, and septic system leachate getting into adjacent rivers and streams may trigger excessive algal and plant blooms which deplete the dissolved oxygen in the water. Too little oxygen harms young fish populations and eventually also causes plants to die. Algal blooms at the surface can interfere with photosynthesis of submerged plants by blocking sunlight, causing them to die. Their decomposition results in further depletion of dissolved oxygen which sets off a vicious downward cycle. Excess plants and algae, dead or alive, clog up waterways, and cause odors hurting both recreational values of the river and adjacent property values. Excessive phosphates in waters used for public water supply may lead to taste and/or odor problems due to its stimulation of excessive algae growth, while nitrates, which are difficult to remove from source water, may, in excessive concentrations, make the water unhealthful for animals and/or humans to drink.

Pesticides and herbicides can get into rivers via surface runoff from roads, agriculture, lawns, and golf courses. Many of these substances are carcinogens and can kill aquatic organisms directly and/or accumulate in the food chain as well as harm water supplies. After application, many pesticides and herbicides are bound to soil particles, thus, if soil erodes from a nearby field and enters a stream, the pollutant will also enter. Pesticides and herbicides getting into riparian areas used for public or private water supplies can be expensive and/or difficult to remove from drinking water, and those that are not effectively removed may pose carcinogenic or other health risks or cause the abandonment of the supply.

Pathogens (viruses and harmful bacteria, e.g.) can get into rivers from a variety of sources, including animal feces washing off urban streets, malfunctioning and/or overburdened sanitary and storm sewers, poor agricultural practices, and septic systems sited too close to rivers and streams. Excessive concentrations of pathogens in rivers and streams can result in brief or extended closures of swimming areas and sources of public or private water supply. Such closures can have serious adverse economic as well as public health impacts as property values decline, communities lose tourism and tax revenue, etc..

Heavy metals are a common constituent of urban runoff, washing off roads and even galvanized and copper roofs. If these pollutants reach rivers and streams, they can have hidden and long-lasting impacts. Toxic metals such as mercury can kill aquatic organisms directly or accumulate insidiously in the food chain, ultimately killing higher predators that feed on aquatic organisms and making fish unsafe for human consumption. In addition, dissolved metals can harm water supply equipment and degrade the suitability of the water for drinking and other uses.

Although not ordinarily thought of as a pollutant, excessive sediment getting into rivers and streams can cause a wide variety of adverse impacts. Sediments can get into rivers by numerous means, including soil washed and/or wind-blown off of bare earth exposed during farming, forestry or mining operations and construction sites. Excessive sediments can also be a byproduct of excessive streambank erosion caused by removal of streamside forests and/or an increase in impervious surfaces upstream. Excessive sediment into rivers reduces flood storage, as eroded sediments settle out of the current and fill channels and deeper spots on the river so they can no longer convey or hold as much water. This reduction of storage capacity results in increasing peak discharges and increased likelihood of flood damage.

Sediments also increase stream turbidity (cloudiness), which leads to increases in stream temperature, which contributes to excessive algal growth and increased pathogenic activity. Many nutrients and other pollutants are bound to sediments, so sediments can serve as a means for the transfer of nutrients and chemicals such as fertilizers and pesticides from adjacent lands into the river. Excessive sediments can harm water supplies by damaging water treatment pumps and other equipment, increasing treatment costs to remove the sediment, and reducing reservoir storage capacity. It can also decrease river bottom infiltration, reducing the yield of nearby wells. In addition, chlorine is generally less effective as a water treatment disinfectant if the water has a high turbidity level.

Sediment can be particularly harmful to fisheries. In excessive quantities, sediment kills small bottom dwelling stream animals and destroys fish habitat. The cloudiness of soil particles suspended in water irritates the gills of fish and makes them more prone to disease. The soil that settles on the stream bottom smothers insect larvae and other bottom dwelling organisms that fish depend on for food. It also smothers fish eggs and embryos in their gravel nests. The reproductive habits of trout illustrates this well. A trout selects clean gravel to make a nest and lay its eggs. Cool clean water normally passes through the nest and supplies oxygen to the eggs. Silt settling on the gravel nest blocks the oxygen-rich water, causing the eggs to suffocate and die.

Thermal pollution also has a significant adverse impact on rivers and streams. The two major land use activities on riparian lands responsible for thermal pollution are the removal of shading streamside forests from and/or placing impervious surfaces in riparian areas, both of which lead to increased stream temperature. Water holds less oxygen as it becomes warmer. As a result, less oxygen is available for respiration by aquatic organisms. Furthermore, in the case of some fish species such as trout, higher temperatures increase their metabolic rate and need for oxygen at the very time that less oxygen is available. Other negative effects of increased water temperature include odors and more profuse growth of some pathogens and other bacteria. Small increases in water temperature can also cause nutrients that are sediment-bound at lower temperatures to break free, resulting in a substantial increase in the quantity of nutrients released into the water. When combined with sunlight from a treeless shoreline, these "free" nutrients can create large algal blooms which further diminish water quality.

Last but not least, the construction, maintenance and use of roads and other paved surfaces are responsible for a whole host of pollutants, including all of the above categories as well as motor oil, gasoline and other automobile fluids and residue from tire treads and brake linings. Sand applied to roads and parking lots during the wintertime to promote safe driving can nevertheless become a major source of sediment pollution if it is eventually carried by wind and water into rivers and streams. Road sand not only degrades rivers for fisheries (e.g., smothering gravel spawning beds) and flood control (sand reduces flood storage capacity), but the sand itself carries pollutants from automobiles and other pollutants hitting the pavement into adjacent streams. Even snow on and along roadways can be a significant source of pollution once it melts or is dumped alongside or into rivers and streams. Snowbanks accumulate roadway pollutants such as petroleum products/additives and metals, the direct application of salt and anti-skid grits, even deteriorated pieces of the roadway itself. High levels of chloride, lead, iron, phosphorous, biochemical oxygen demand and total suspended solids have been reported in snow dump runoff. DEP issued a policy for snow and ice management in late fall of 1996 to address this problem.

How do naturally vegetated riparian areas act to prevent pollution of adjacent rivers, streams and groundwater?

The most obvious pollution prevention function of riparian areas kept in a naturally vegetated condition is that such land is not in and of itself a pollution generator. In other words, the more that riparian lands along a particular watercourse are maintained in a naturally vegetated state as opposed to being converted to other pollution-generating land uses, the less pollution will get into that waterway from the riparian lands themselves. As an increasingly larger share of pollution in our rivers and streams is attributable to nonpoint source pollution originating from development of riparian areas along rivers and streams, merely keeping our remaining undeveloped riparian areas in a naturally vegetated condition is a highly effective means of pollution prevention.

But riparian lands maintained in a naturally vegetated state do much more than simply take the place of other pollution-generating land uses. Streamside forests and other naturally-vegetated riparian areas act as a living filter to intercept and absorb excess nutrients, sediment and other pollutants carried along in runoff from adjacent development as well as by the river itself. Several different and complementary processes within the vegetated riparian area collaborate to accomplish this. First, living, decaying and dead vegetation within the riparian area provide a multitude of barriers that slow down and intercept runoff and wind-blown sand and silt from adjacent lands before they reach rivers and streams.

This slowdown enables a number of pollution-attenuating functions to occur. Much if not most of the runoff infiltrates into the porous, uncompacted soil within the riparian area, where sediments (many of which have pollutants bound to them) are trapped and where excess nutrients, heavy metals and many other pollutants are either taken up onto plant surfaces (adsorption), incorporated and sequestered into plant tissues (absorption), or are broken down into less harmful substances by soil bacteria and other microorganisms. Pesticides and other toxics borne into the riparian area by runoff are converted to non-toxic compounds by a number of biochemical processes, including microbial decomposition, oxidation, reduction, hydrolysis, solar radiation and other biodegrading forces at work in the soil and litter of the streamside forest.

A similar pollution-reducing phenomenon occurs in the river itself. Large woody debris (e.g. tree trunks and roots) extending or falling into the water hold back sediments and also provide ample surface area to support a large population of microbes that consume excess nutrients and other pollutants that have already gotten into the water. In the meantime, the streamside forest shades the water, which in turn lowers its temperature, thus enabling it to have a higher dissolved oxygen content necessary for the microbes to effectively metabolize pollutants and the other items in their diet. Keeping stream temperatures cool with shading streamside forests also keeps phosphorous and other sediment-bound pollutants from breaking free and becoming more harmful as dissolved substances.

When rivers are allowed to flood into adjacent vegetated floodplains, these floodplains act as sediment traps and nutrient sinks. When muddy water from streams and rivers rushes into the stillness of floodplain wetlands and forests, the silt in the water adheres to the stalks of water plants and settles to the bottom. As the flood waters recede, the waters returning to the river via the surface or ground are largely cleansed of their excess sediment and nutrients. Riparian wetlands improve water quality by a variety of anaerobic and aerobic processes, that precipitate or volatize certain chemicals from the water column. The accumulation of organic peat characteristic of many riverine wetlands can ultimately lead to a permanent sink for many chemicals coming from adjacent development and/or the river itself. In addition, the high rate of biological productivity of many wetlands can lead to high rates of mineral uptake by, and accumulation in, plant material with subsequent burial in sediments.

Since for certain organisms and chemicals (fecal coliform bacteria, phosphates and nitrates, for example), it is not merely their presence but their overall concentration in the water that controls how harmful they are as pollutants, naturally vegetated riparian areas also perform an important pollution prevention function by helping to dilute concentrations of these pollutants below harmful levels. Precipitation falling on the vegetated buffer combines with surface and/or groundwater flow to dilute concentrations of pollutants generated from adjacent land uses as they flow through the buffer. The cleaner surface and/or groundwater discharge into adjacent rivers and streams from naturally vegetated riparian areas also helps to dilute the concentrations of pollutants already present in those waterways. Degradation results when these natural pollution attenuation processes are overwhelmed by excessive pollutant loading, however.

What are some best management practices (BMPs) for naturally vegetated riparian areas to maintain or enhance their pollution prevention function?

The effectiveness of riparian areas in preventing and reducing pollution is influenced by several factors, including the width and nature of streamside vegetation, the manner in which runoff is discharged into and passes through the vegetated area, and the slope and composition of the soil within the riparian area. A key characteristic of effective vegetated riparian areas is a relatively long detention time between when the polluted runoff enters the riparian area and when it flows or seeps into the adjacent stream. As is the case with wastewater treatment plants and other pollution control mechanisms, generally speaking, the greater the detention time, the greater degree of pollutant reduction.

- **Retain/restore natural riparian vegetation**

There are a number of ways to help ensure riparian areas' pollution prevention function. First and foremost is to retain as much of the area as possible in a naturally vegetated, undisturbed condition, especially the portion of the riparian area that is closer to the adjacent river or stream. In most situations, "naturally vegetated" means native forest cover, as that is how most of our riparian areas were before settlement. Streamside forest vegetation, whether living, decaying or dead, on the ground or fallen or extending into the water, should be left in place wherever possible to maximize its detention capability and allow plenty of time for the breakdown of pollutants by plants and microorganisms. Excessive "tidying up" of riparian areas by leaf raking, brush clearing, removing fallen logs or other removal of plant material from the forest floor and/or streambank can significantly reduce detention time and the opportunity for the riparian area's living filter to beneficially interact with and attenuate water-borne pollutants.

- **Diffuse runoff into riparian areas and discharge as far as possible from the river**

In addition to retaining undisturbed forest cover, riparian areas are most effective at pollution prevention when infiltration opportunities are maximized by discharging polluted runoff from adjacent areas at the outside edge of the area (the edge furthest away from the stream) and in a diffuse manner. Runoff has a strong tendency to concentrate and form a channel. The steeper the slope, the greater the tendency of runoff to form a channel. Vegetated streamside buffers are effective only when runoff is evenly distributed across them and given ample opportunity to infiltrate forest soils and interact with plants and microorganisms. Once a channel is formed, the buffer's living filter is effectively "shortcutted" and will not perform as desired. Buffer shortcutting also occurs when runoff is routed directly to receiving waters through storm sewers, culverts, and other confined drainage ways, often bypassing the buffer entirely. Therefore, it is important to ensure that drainage into buffers is not channelized but is instead spread evenly as sheet flow through use of a level lip spreader or similar mechanism. Compacting soils within riparian areas should be avoided for the same reason (it reduces infiltration).

- **Retain/reestablish a vegetated streamside buffer at least 100' wide**

Buffer width is also important. Generally speaking, the greater the width of a vegetated streamside buffer, the more effective it will be in preventing pollutants generated by adjacent development from getting into adjacent rivers and streams. Studies have consistently shown that naturally vegetated buffers must be at least 100 feet wide to achieve substantial reductions in most constituents of polluted runoff. A few pollutants (viruses, e.g.) can travel further distances and need greater buffer widths to be effectively filtered out. Dilution of contaminant-rich runoff by rain falling on the buffer is directly related to buffer width (i.e., the wider, the better). Maximum stream shading for maintaining beneficial lower stream temperatures is achieved when the riparian forest buffer is at least 80 feet wide on both sides of the stream.

- **Avoid development on steep slopes and/or permeable soils**

Last but not least, slope and soil composition affects the ability of riparian areas to prevent pollution from entering adjacent water bodies. It is just as, if not more important, from a water quality standpoint to keep sources of pollution such as septic systems as far away from rivers bordered by uplands with drier permeable soils as it is for rivers bordered by wetlands. This is because riparian uplands are, generally speaking, not as efficient in filtering pollutants as are riparian wetlands. First, uplands typically are more steeply sloped than wetlands. This affects the detention time of water on or below the surface. Generally speaking, the steeper the slope, the shorter the detention time. The shorter the detention time, the less opportunity plants, microbes and other organisms within the riverine upland soils have to act on and absorb waterborne pollutants. The fact that wetland soils are usually flat and already saturated means that water passing on or through them moves at a relatively slower rate. The increased detention time gives wetland organisms a greater opportunity to filter out and absorb waterborne pollutants and excess nutrients before the water reaches the adjacent river. Second, riverine wetlands typically have a higher rate of biological activity (due to a greater diversity and concentration of flora and fauna, most notably of the macroinvertebrate and microscopic kind) than do riverine uplands. This also results in a generally higher level of pollutant and nutrient removal in wetlands than in uplands.

- **Consider retrofitting existing riparian development with structural pollutant controls where restoration of vegetated streamside buffer is not possible**

In areas where riparian lands have already been developed and vegetated streamside buffers no longer exist and cannot be restored, it is important, where opportunities arise, to implement more structural pollution control technologies to reduce nonpoint source pollutant loadings to adjacent streams. DEP recently issued a Stormwater Management Guidance document to assist with the identification and implementation of stormwater BMPs.

Fact Sheet #8: The Importance of Protecting Riparian Areas along Smaller Brooks and Streams

WHY DO RIPARIAN AREAS ALONG SMALLER STREAMS NEED AND DESERVE AT LEAST AS MUCH PROTECTION AS LARGER STREAMS?

It is equally, if not more, important from a scientific perspective to preserve corridors of natural vegetation along the smaller brooks and streams as it is to maintain them along the larger rivers. The water quality and quantity in mainstem rivers is largely determined by what they receive from their many smaller tributaries. Many of the degrading impacts of developments encroaching on riparian areas along these tributaries are carried downstream and are often amplified once they drain into the larger mainstem rivers. On the other hand, tributaries with relatively undisturbed riparian vegetation contribute steady amounts of clean, cool water to the mainstems and provide organic matter needed by aquatic organisms downstream. In addition, the fragility of riparian areas is often accentuated in small headwater stream reaches. These small streams are the most vulnerable to human disturbance because they respond dramatically and rapidly to alterations on adjacent lands and are the most sensitive to changes in riparian vegetation in the surrounding watershed. Here are some additional reasons why preserving and/or restoring naturally vegetated riparian areas along the smaller brooks and streams is especially important:

Flood Control and Storm Damage Prevention:

A large proportion of the water in rivers is contributed by the smaller tributaries. If riparian areas along these brooks and streams is altered in a manner (e.g., the removal of forest cover and/or the placement of buildings) that impairs their ability to detain and absorb floodwater and stormwater, the cumulative impact of streams discharging flood and storm flows into rivers at a greater volume and velocity will result in worsening flooding and storm damage to existing structures and mainstem river communities downstream, even if mainstem floodplains are safeguarded against further development. In addition, the smaller headwater tributaries tend to be located on some of the steepest-sloping and erosion-prone lands within a watershed. Furthermore, all other things being equal, the same development is likely to have a relatively greater negative impact on flooding conditions in an adjacent small stream than the same project along a larger river (e.g., the runoff from one large parking lot can itself be enough to overwhelm a small stream channel).

Wildlife Habitat:

Wildlife use of riparian areas along smaller brooks and streams, although somewhat different in character from the major rivers, is still quite extensive. Many species utilize vegetated riparian areas during all or part of their life cycle regardless of the size of the adjacent watercourse. In fact, several sensitive species thrive only in cold, unpolluted springs and small streams. Last but not least, as most of the nation's river corridors have already been extensively developed, the areas which remain in a relatively pristine condition (and as such are likely to have the best quality wildlife habitat) tend to be located on the smaller tributaries.

Fisheries:

It is particularly important from a fisheries protection perspective to preserve corridors of natural vegetation along the smaller brooks and streams. Most of the annual flow in the smaller headwater streams is provided by groundwater that, in turn, is replenished by rainwater falling onto and infiltrating the soil under vegetated areas. Since water seeps slowly through the soil, the surface water flowing in streams can represent rainwater that fell days, weeks or even months ago. This regular, continuous seepage of groundwater that keeps streams flowing is called "baseflow".

Baseflow is critical to stream life and water quality. Low flow periods are typically the most stressful periods for aquatic organisms, resulting in crowding due to less available habitat, elevated water temperatures in the summer and greater freezing in the winter. Sportfish, fish food animals, and water plants require a stable, continuous flow of water, particularly during dry periods. Groundwater discharge is a major source of streamflow for smaller streams, especially during hot and dry summers, where the discharge both augments the streamflow and mitigates harmful temperature increases. This groundwater discharge is key to maintaining adequate water levels and temperatures in streams to support aquatic life.

Because of their small ratio of stream bottom width to shoreline, small headwater streams are especially vulnerable to harmful increases in temperature due to removal of shading from streamside forests. This removal of shading will also increase evaporation rates, making the streams lose water at the very time that groundwater replenishment is diminished due to the removal of these same forests. As a result, the failure to maintain vegetative cover on or keep impervious surfaces out of riparian areas adjacent to smaller brooks and streams is likely to increase the frequency, duration and severity of low flow conditions. In smaller streams, where flows are already modest in size, a reduction in baseflow is especially harmful. Small streams deprived of groundwater flow may even dry up completely, a condition that is obviously extremely stressful if not fatal to fish and other aquatic organisms.

Optimum spawning sites for important game fish frequently exist in headwater streams, even though these same fish may spend the remaining time in the larger rivers. Fish often retreat to these cooler tributaries when the mainstems get too warm for them. An increase in water temperature in headwater streams may result in a decrease in fish reproduction and useable habitat. Fortunately, the effectiveness of streamside forest buffers at controlling water temperature increases as stream size decreases. And if water temperatures are kept cool by streamside forests in the upper portion of the watershed, the tributaries will provide a significant beneficial cooling effect on the main watercourses during the summer, when flows are lowest and temperatures are highest.

Even where inaccessible to fish, the small headwater brooks and streams and adjacent riparian areas remaining in a relatively pristine condition provide high levels of water quality and quantity, sediment control, nutrients and woody debris for downstream reaches of the watershed. Thus, especially in the highly degraded systems, headwater streams serve as critical ecological anchors for riverine systems and important refuges for biodiversity. As many of the fisheries mainstem rivers have already suffered serious degradation, it is the smaller tributary streams, especially the "coldwater" streams capable of supporting naturally reproducing wild trout, where preventing further encroachments into riparian areas is arguably of greatest value from a fisheries perspective.

Groundwater and Public Water Supply Protection:

As mentioned previously, groundwater can and often does reemerge as surface water, and groundwater discharge into rivers and streams has a beneficial effect on both the quantity and quality of water in the recipient watercourse. This is particularly true for the smaller headwater streams, where most of their annual flow is attributable to groundwater reentering the surface as natural spring seeps that, in turn, are replenished by rainwater falling onto and infiltrating the soil under vegetated areas. Groundwater discharge is a major source of streamflow for smaller streams, and is key to maintaining adequate water levels and cooler temperatures in streams to prevent sediment-bound pollutants from breaking free and to dilute pollutant concentrations below harmful levels.

The failure to maintain vegetative cover on or keep impervious surfaces out of riparian areas adjacent to smaller brooks and streams is likely to result in a significant loss of groundwater recharge and increase the frequency, duration and severity of low flow conditions. Small streams deprived of groundwater flow may even dry up completely, a condition that obviously limits their value for public and private water supplies. Last but not least, as most of the major rivers continue to have degraded water quality, due in part to their role in assimilating municipal wastewater and other point source discharges, it is the smaller headwater streams and watersheds that remain in a relatively pristine and uncontaminated condition that are likely to have the greatest value for public water supplies.

Pollution Prevention:

Due to their modest size, small streams and brooks are especially vulnerable to degradation by excessive sediment, nutrients and other pollutants, simply because there is a smaller volume of water available to flush out and/or and assimilate these pollutants. All other things being equal, the same development is likely to have a relatively greater negative impact on a small stream's water quality than the same project along a larger river (the lower water volume in the smaller watercourse will result in higher nonpoint source pollution concentrations). In addition, smaller, shallower rivers and streams are also especially susceptible to stream heating, and excessive algae growth, dissolved oxygen depletion, and pathogenic organism activity are all triggered by higher stream temperatures.

Maintaining a living filter of natural vegetation along smaller brooks and streams is key to intercepting pollutants before they reach and degrade the sensitive smaller streams as well as enabling groundwater recharge and low flow augmentation to help maintain cooler temperatures and dilute pollutant concentrations. In addition, studies have found that streamside wetlands along smaller streams are more efficient at absorbing nutrients and sediments from adjacent waterways than along the larger rivers because a greater proportion of the water in smaller watercourses comes into direct contact with the cleansing action of streamside wetland plants and microorganisms.

A large proportion of the water in the state's rivers is contributed by the smaller tributaries. If water quality is allowed to degrade in these smaller tributaries by the placement of polluting activities in the riparian areas along smaller brooks and streams, mainstem riverine water quality will deteriorate regardless of protected riparian vegetation along the larger rivers. In addition, the typically cleaner flow of tributaries performs a key role in diluting concentrations of pollutants in the mainstems coming from industrial and other wastewater treatment discharges. If the water quality in the tributaries is allowed to degrade, then they cease to perform this important dilution function for the major rivers.

Contributions by Russell Cohen, Rivers Advocate, Riverways Program, Massachusetts Department of Fisheries, Wildlife and Environmental Law Enforcement 1997.